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(54) **Rolled steel having few inclusion defects**

(57) The present invention provides rolled steel having few inclusion defects suitable for steel sheets used for automobiles, steel sheets used for deeply drawn cans and steel pipes, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of one of the crystallized phase, the principal component of which is titanium oxide, and the crystallized phase, the principal component of which is alumina, and further composed of at least one of the crystallized phase, the principal component of which is CaO, and the crystallized phase, the principal component of which is MgO, and the crystallized phases of oxide inclusions exist in steel.

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Description

[0001] The present invention relates to rolled steel having few inclusion defects suitable for producing steel sheets for automobile use, steel sheets for making deeply drawn cans, and steel pipes.

[0002] In general, pieces of rolled steel such as steel sheets and steel pipes are made of aluminum killed steel obtained when molten steel made by a converter, which has not been deoxidized yet, is deoxidized by aluminum. After the killed steel has been rolled, surface defects and internal defects such as sliver flaws (linear flaws) caused in the process of cold rolling, cracks and pin holes caused in the case of deep drawing and defects detected in weld zones of steel pipes by the ultrasonic test are caused by inclusions in some cases. It is known that those inclusion defects are caused by the inclusion of oxides, such as alumina, created in the process of deoxidation conducted in molten steel in refining.

[0003] In order to remove the oxide inclusions, the following methods have been conventionally adopted.

(1) A deoxidizing agent such as aluminum is thrown into molten steel in the process of tapping from a converter so that the period of time, in which the oxide inclusions are raised to the surface of molten steel by coagulation and coalescence, can be extended as much as possible.

(2) Rise and separation of oxide inclusions are facilitated when molten steel is forcibly agitated by the treatment of CAS (Composition Adjustment by Sealed Argon Gas Bubbling) or RH which is one of the secondary refining methods.

(3) Alumina is changed into $CaO-Al_2O_3$ by adding Ca into molten steel so that it can be easily crushed in the process of rolling, and the alumina becomes harmless.

[0004] However, the following problems may be encountered in the above methods (1) and (2). Effects of the above methods (1) and (2), by which oxide inclusions can be raised to the surface of molten steel so that the inclusions can be separated from molten steel, are limited. Therefore, it is impossible to perfectly prevent the occurrence of sliver flaws, cracks, pin holes and UST defects. Further, the following problems may be encountered in the above method (3) in which oxide inclusions are reformed by Ca. Material of Ca is expensive, and the yield is very low. Accordingly, the cost of alloy is raised. Further, particles of $CaO-Al_2O_3$, which are created when Ca is added into molten steel, are enlarged, and the thus created particles of $CaO-Al_2O_3$ can not be raised to the surface of molten steel, that is, the thus created particles of $CaO-Al_2O_3$ remain in molten steel. In this case, defects are caused by the particles of $CaO-Al_2O_3$.

SUMMARY OF THE INVENTION

[0005] The present invention has been accomplished to solve the above conventional problems. It is an object of the present invention to provide rolled steel having few inclusion defects in which particles of oxide inclusions are kept fine and capable of being dispersed in rolled steel.

[0006] In order to solve the above problems, the present invention provides rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium-oxide, and a crystallized phase, the principal component of which is alumina, and the crystallized phases of oxide inclusions exist in steel.

[0007] In the same manner, in order to solve the above problems, the present invention provides rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium-oxide, and a crystallized phase, the principal component of which is alumina, and further composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, and the crystallized phases of oxide inclusions exist in steel.

[0008] It is preferable that the crystallized phases of oxide inclusions are dispersed in rows in the direction of rolling near the center of a piece of rolled steel. It is preferable that Micro-Vickers hardness of the oxide inclusions at the room temperature is in a range from 600 to 1300 Hv. Further, it is preferable that the maximum diameter of the particles of oxide inclusions obtained by slime extraction is not more than 300 μm. Furthermore, it is preferable that the number of the particles of oxide inclusions obtained by slime extraction, the diameter of which is not less than 38 μm, is not more than 50 pieces/kg.

[0009] A preferred embodiment of the present invention is explained as follows.

[0010] In the present invention, rolled steel includes steel sheets, steel pipes, shape steel, bar steel and wire rods.

The basic composition of the rolled steel is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %.

[0011] In the present invention, rolled steel includes steel sheets, steel pipes, shape steel, bar steel and wire rods. The basic composition of the rolled steel is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, and the selective composition of the rolled steel is Ca: not more than 50 ppm and Mg: not more than 50 ppm, wherein at least one of Ca and Mg is contained.

[0012] Carbon is an essential element to stably enhance the mechanical strength of steel. Therefore, the content of carbon is adjusted in a range from 0.0002 to 0.7% according to the desired mechanical strength of material. In order to ensure the mechanical strength or hardness, it is necessary that rolled steel contains carbon at not less than 0.0002%, however, when the content of carbon is higher than 0.7%, the workability is lowered. Therefore, the content of carbon is kept so that it cannot exceed 0.7%.

[0013] The reasons why the contents of other components are kept in the above ranges are described as follows.

[0014] The reason why the content of Si is kept in a range from 0.001 to 0.5% is described below. When the content of Si is in a range lower than 0.001%, it becomes necessary to conduct pretreatment of material, and the cost of refining is increased, that is, it is not economical to keep the content of Si in a range lower than 0.001%. When the content of Si is higher than 0.5%, defects are caused in the process of plating, and the surface property and the corrosion resistance are impaired.

[0015] The reason why the content of Mn is kept in a range from 0.005 to 2.0% is described below. When the content of Mn is lower than 0.005%, the refining time is extended, which is not economical. When the content of Mn exceeds 2.0%, the workability at steel is greatly impaired.

[0016] The reason why the content of P is kept in a range from 0.001 to 0.05% is described below. In order to keep the content of P lower than 0.001%, it takes time to treat molten pig iron and the cost is raised, which is not economical. When the content of P exceeds 0.05%, the workability of steel is greatly impaired.

[0017] The reason why the content of S is kept in a range from 0.0005 to 0.15% is described below. In order to keep the content of S lower than 0.0005%, it takes time to treat molten pig iron and the cost is raised, which is not economical. When the content of S exceeds 0.15%, the workability and the corrosion resistance of steel are greatly impaired.

[0018] The reason why the content of Ti is kept in a range from 0.001 to 0.25% is described below. When the content of Ti is lower than 0.001%, it becomes difficult to cast molten steel. When the content of Ti is higher than 0.25%, only titanium oxide, which tends to become clusters, is created, and the diameters of inclusion particles are enlarged. As a result, sliver flaws are caused in the same manner as that of alumina.

[0019] The reason why the content of dissolved Al (sol Al) is kept in a range from 0.001 to 0.1% is described below. When the content of dissolved Al is lower than 0.001%, it impossible to conduct a sufficient deoxidation treatment. When the content of dissolved Al exceeds 0.1%, only alumina is created, and surface defects and internal defects are caused.

[0020] Both Ca and Mg form "crystallized phases", the principal component of which is oxide, in the oxide inclusions.

(1) Therefore, they contribute to make the crystallized phase itself fine.

(2) Also, they contribute to crushing the inclusion so as to make the inclusion fine along an interface of the fine crystallized phase in the process of rolling. The reason why at least one of Ca, the content of which is kept lower than 50 ppm, and Mg, the content of which is kept lower than 50 ppm, is contained is described as follows. Since the vapor pressure of Ca and that of Mg are high and the yield of Ca and that of Mg are low, the cost is raised when the contents of Ca and Mg are increased to a value higher than 50 ppm. The reason why the lower limits of Ca and Mg are not stated plainly is described as follows. Even when the concentration of Ca and that of Mg are lower than the lower limit of analysis in the composition analysis of steel, it is possible to make the inclusions contain at least one of CaO and MgO sufficiently.

[0021] The present invention provides rolled steel, the basic composition of which is described above, and the oxide inclusions created in the processes of deoxidation and coagulation are mainly composed of a crystallized phase, the principal component of which is Ti oxide, and a crystallized phase, the principal component of which is alumina, and the crystallized phases of oxide inclusions are dispersed in steel.

[0022] The present invention provides rolled steel, the basic composition and the selective composition of which are described above, and the oxide inclusions created in the processes of deoxidation and coagulation are mainly composed of a crystallized phase, the principal component of which is Ti oxide, and a crystallized phase, the principal component of which is alumina, and also composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, and the crystallized phases of oxide inclu-

sions are dispersed in steel. In this case, the crystallized phase is a crystal phase in a solid state, that is, the crystallized phase does not include a glass phase in a solid state. That is, when there is provided a crystallized phase composed of at least two phases of the crystallized phase, the principal component of which is Ti oxide, and the crystallized phase, the principal component of which is alumina, or alternatively when there is provided a crystallized phase composed of at least three phases of the crystallized phase, the principal component of which is Ti oxide, the crystallized phase, the principal component of which is alumina, and at least one of the crystallized phase, the principal component of which is CaO, and the crystallized phase, the principal component of which is MgO, the crystallized phase itself is made to be fine, and further the crystallized phase is easily crushed to more fine particles. As a result, the occurrence of flaws such as sliver flaws can be prevented, and rolled steel having few inclusion defects can be obtained.

[0023] It is preferable that the crystallized phases of oxide inclusions are dispersed in rows in the direction of rolling near the center with respect to the thickness of a piece of rolled steel. Since the oxide inclusions seldom exist on the surface of the piece of rolled steel, it is possible to obtain rolled steel having few inclusion defects.

[0024] When consideration is given to the deformability of steel in the process of rolling conducted after the completion of hot rolling, it is preferable that Micro-Vickers hardness of oxide inclusions at the room temperature is in a range from 600 to 1300 Hv. The reason why the hardness is kept in the above range is described as follows. When the hardness is lower than 600 Hv, the inclusions are excessively elongated. When the hardness is higher than 1300 Hv, the inclusions are seldom elongated, and it becomes difficult to crush and disperse the inclusions by rolling.

[0025] When the maximum diameter of the particles of oxide inclusions obtained by slime extraction is not larger than 300 μm and further the number of the particles of oxide inclusions, the diameters of which are not less than 38 μm, is kept to be not more than 50 pieces/kg, there is little possibility that the particles of oxide inclusions on the surface of rolled steel are drawn out in rows, and it is possible to obtain rolled steel having few inclusion defects.

[0026] As described above, the present invention provides rolled steel, the characteristics of which are described as follows. Oxide inclusions created in the processes of deoxidation and coagulation are mainly composed of a crystallized phase, the principal component of which is Ti oxide, and a crystallized phase, the principal component of which is alumina. When the crystallized phases concerned are dispersed in rolled steel, oxide inclusions are made to be oxides composed of the two phases of the crystallized phase, the principal component of which is Ti oxide, and the crystallized phase, the principal component of which is alumina, and the crystallized phases of the oxides are made to be fine. Next, the oxide inclusions are further crushed and dispersed by rolling in rows on an interface of the crystallized phase, the particles of which are made to be fine. In this way, when the inclusion is made to be inclusion of the crystallized phase, the principal component of which is fine particles of Ti oxide, and/or the crystallized phase, the principal component of which is alumina, the product defects, which are caused by oxide inclusions, such as sliver flaws in the process of cold rolling, cracks, pin holes and defects detected in the process of UST, can be greatly reduced.

[0027] Further, the present invention provides rolled steel, the characteristics of which are described as follows. Oxide inclusions created in the processes of deoxidation and coagulation are mainly composed of a crystallized phase, the principal component of which is Ti oxide, and a crystallized phase, the principal component of which is alumina. Further, oxide inclusions created in the processes of deoxidation and coagulation are mainly composed of at least one of the crystallized phase, the principal component of which is CaO, and the crystallized phase, the principal component of which is MgO. When the crystallized phases concerned are dispersed in rolled steel, oxide inclusions are made to be oxides composed of at least three phases of the crystallized phase, the principal component of which is Ti oxide, the crystallized phase, the principal component of which is alumina, and at least one of the crystallized phase, the principal component of which is CaO, and the crystallized phase, the principal component of which is MgO. Next, the oxide inclusions are further crushed and dispersed by rolling in rows on the interface of the crystallized phase, the particles of which are made to be fine. In this way, when the inclusions are made to be inclusions of the crystallized phase, the principal component of which is fine particles of Ti oxide, and/or the crystallized phase, the principal component of which is alumina, and also when the inclusions are made to be inclusions of at least one of the crystallized phase, the principal component of which is CaO, and the crystallized phase, the principal component of which is MgO, the product defects, which are caused by oxide inclusions, such as sliver flaws in the process of cold rolling, cracks, pin holes and defects detected in the process of UST, can be greatly reduced.

Example 1

[0028] Pieces of rolled steel were produced by a vertical bend-type continuous casting machine under the condition that the slab size was 245 mm thickness × 1200 to 1600 mm width, the casting speed was 1.4 to 1.7 m/min, and the temperature of molten steel in the tundish was 1560°C. After that, the slabs were hot-rolled, and then the pieces of hot-rolled steel were subjected to acid pickling, cold rolling, annealing and secondary cold rolling when necessary. In this way, products shown on Table 1 were produced.

[0029] Deoxidizing alloy used in the production process and the principal components contained in the crystallized phase of oxide inclusions are shown in Table 2. The hardness of oxide inclusions, the existing formation and the ratio

of occurrence of defects are shown in Table 3. It can be seen from these tables that the present invention can greatly reduce the defects of products caused by oxide inclusions so that the productivity can be enhanced.

[0030] The components of the crystallized phase of inclusions shown in Table 2 were identified in such a manner that the inclusions extracted from a piece of rolled steel of full thickness by means of slime electrolytic extraction (the minimum mesh was 38 μm) was subjected to component identification by SEM (Scanning Electron Microscope) having EDX (Energy Dispersive X-ray Spectrometer). Further, concerning the additional component detected in the above component identification, the content was found by the integral intensity of the peak of the characteristic X-rays.

[0031] The existing formation of inclusion, which is shown in Table 2, on the section in the rolling direction was determined by the profile of the product as follows.

[0032] In the case of a sheet, the full thickness of a section parallel to the rolling direction was observed by an optical microscope, and the existing inclusion formation was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50) which was taken at a position where the inclusion exists.

[0033] In the case of a wire, the full thickness of a section parallel to the drawing direction (the rolling direction) was observed by an optical microscope, and the existing inclusion formation was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50) which was taken at a position where the inclusion exists.

[0034] In the cases of a pipe and rod, local positions, which were located below the front or the rear surface by 0.1 mm, 1/8t, 1/4t, 3/8t, 1/2t, 5/8t, 3/4t and 7/8t wherein t is thickness, were observed by an optical microscope, and the existing inclusion formation was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50 for each local position) which was taken at a position where the inclusion exists.

[0035] In this connection, meanings of *1 to *9 shown in Tables 2 and 3 are described as follows.

*1: Level of dissolved oxygen, A: Not less than 400 ppm, B: Not less than 200 and lower than 400 ppm, C: Not less than 100 and lower than 200 ppm, and D: Lower than 100 ppm

*2: Principal component in the crystallized phase is controlled by a quantity of alloy added in the process of deoxidation.

*3: MnO and SiO_2 are contained by not more than 10 weight % as additional components in the crystallized phase.

*4: TiO_x is contained by not more than 5 weight % as an additional component in the crystallized phase.

*5: Al_2O_3 is contained by not more than 5 weight % as an additional component in the crystallized phase.

*6: An average is calculated at the room temperature for 10 particles of inclusion when a load of 25 g is given to each of three positions with respect to one type of inclusion.

*7, *8: The maximum diameter of the inclusion particles and the number of the inclusion particles are controlled by dissolved oxygen before deoxidation.

The method of measuring the maximum diameter of the inclusion particles is described below. Inclusions, which were extracted by means of slime electrolytic extraction (the minimum mesh was 38 μm) from a piece of rolled steel of full thickness of the weight of 1 ± 0.1 kg, were photographed by a stereoscopic microscope, the magnification of which was 40, and the averages of the major and the minor axis of the inclusion particles on the photograph were found with respect to all the inclusion particles, and the maximum value of the thus found averages was determined to be the maximum diameter of the inclusion particles. The number of the inclusion particles was found as follows. The number of all the inclusion particles, which was extracted by means of slime electrolytic extraction (the minimum mesh was 38 μm) and observed by an optical microscope (the magnification was 100) was converted into the number per the unit of 1 kg.

*9: The ratio of occurrence of defects is determined by the following formulas.

In the case of a sheet, the ratio of occurrence of
sliver flaws on the surface of the sheet is (total length of sliver flaws/length of a coil)

In the case of a pipe, the ratio of occurrence of
UST defects in the electroseamed zone is (number of pipes
in which the defects occurred/number of inspected pipes)

In the case of a rod and wire, the ratio of
occurrence of surface flaws is (number of coils in which defects occur/total number of inspected coils)

Table 1

	No.	Profile of product	Composition of steel (mass %, however, the rest are iron and inevitable impurities)						
			C	Si	Mn	P	S	Ti	sol. Al
Inventive example	A1	Sheet	0.0005	0.039	0.58	0.018	0.006	0.060	0.050
Inventive example	A2	Sheet	0.0025	0.005	0.80	0.028	0.012	0.002	0.002
Inventive example	A3	Sheet	0.0045	0.012	0.15	0.042	0.018	0.018	0.008
Inventive example	A4	Sheet	0.0070	0.021	0.35	0.007	0.023	0.034	0.019
Inventive example	A5	Sheet	0.0023	0.014	0.38	0.020	0.014	0.020	0.007
Inventive example	A6	Sheet	0.0047	0.020	0.56	0.034	0.020	0.038	0.017
Inventive example	A7	Sheet	0.0066	0.036	0.85	0.044	0.025	0.082	0.065
Inventive example	A8	Sheet	0.0007	0.007	0.12	0.005	0.005	0.003	0.001
Inventive example	A9	Sheet	0.02	0.086	0.68	0.016	0.004	0.060	0.030
Inventive example	A10	Sheet	0.04	0.007	0.96	0.025	0.011	0.001	0.002
Inventive example	A11	Sheet	0.07	0.033	0.16	0.040	0.029	0.017	0.010
Inventive example	A12	Sheet	0.10	0.059	0.42	0.005	0.025	0.035	0.021
Inventive example	A13	Sheet	0.03	0.005	0.14	0.018	0.016	0.022	0.008
Inventive example	A14	Sheet	0.05	0.042	0.45	0.035	0.019	0.036	0.018
Inventive example	A15	Sheet	0.13	0.063	0.73	0.046	0.023	0.093	0.073
Inventive example	A16	Sheet	0.01	0.093	0.93	0.006	0.006	0.002	0.003
Inventive example	A17	Sheet	0.0070	0.014	0.17	0.035	0.015	0.015	0.035
Inventive example	A18	Sheet	0.03	0.042	0.41	0.044	0.007	0.050	0.003
Inventive example	A19	Pipe	0.023	0.40	1.24	0.008	0.0005	0.230	0.09
Inventive example	A20	Pipe	0.13	0.021	1.78	0.011	0.05	0.003	0.002
Inventive example	A21	Pipe	0.25	0.15	0.14	0.015	0.0095	0.080	0.035
Inventive example	A22	Pipe	0.34	0.28	0.69	0.004	0.014	0.157	0.068
Inventive example	A23	Pipe	0.11	0.17	0.71	0.005	0.008	0.093	0.038
Inventive example	A24	Pipe	0.27	0.27	1.31	0.012	0.07	0.165	0.053
Inventive example	A25	Pipe	0.31	0.015	1.92	0.017	0.01	0.242	0.085
Inventive example	A26	Pipe	0.015	0.16	0.09	0.003	0.022	0.006	0.006
Inventive example	A27	Rod	0.54	0.40	1.24	0.008	0.025	0.210	0.08
Inventive example	A28	Rod	0.58	0.021	1.78	0.011	0.063	0.005	0.004
Inventive example	A29	Rod	0.62	0.15	0.14	0.015	0.101	0.065	0.032
Inventive example	A30	Rod	0.65	0.28	0.69	0.004	0.14	0.140	0.075
Inventive example	A31	Rod	0.59	0.17	0.71	0.005	0.053	0.080	0.035
Inventive example	A32	Rod	0.61	0.27	1.31	0.012	0.10	0.155	0.051
Inventive example	A33	Wire	0.67	0.015	1.92	0.017	0.135	0.23	0.088
Inventive example	A34	Wire	0.52	0.16	0.09	0.003	0.018	0.008	0.003
Comparative example	B1	Sheet	0.0005	0.012	0.15	0.028	0.023	0.015	0.035
Comparative example	B2	Sheet	0.04	0.059	0.42	0.040	0.013	0.050	0.002
Comparative example	B3	Pipe	0.25	0.17	0.71	0.004	0.07	Ca:30 ppm	0.060
Comparative example	B4	Rod	0.65	0.27	1.31	0.005	0.135	0.000	0.003
Comparative example	B5	Pipe	0.27	0.015	0.75	0.015	0.082	0.002	0.110
Comparative example	B6	Rod	0.67	0.16	1.42	0.002	0.147	0.260	0.003

Table 2

	No.	Deoxidizing alloy	Level of dissolved oxygen before adding deoxidizing alloy *1	Principal component in crystallized phase *2	Existing inclusion formation on the section in the rolling direction
Inventive example	A1	FeTi, Al	B	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A2	FeTiAl	B	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A3	FeTi, Al	B	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A4	FeTiAl	B	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A5	FeTi, Al	B	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A6	FeTiAl	B	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A7	FeTiAl	B	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A8	FeTi, Al	B	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A9	FeTiAl	C	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A10	FeTi, Al	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A11	FeTiAl	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A12	FeTi, Al	C	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A13	FeTiAl	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A14	FeTiAl	C	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A15	FeTi, Al	C	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A16	FeTiAl	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A17	FeTi, Al	A	TiO_x, Al_2O_3	Dispersion over the entire sheet thickness
Inventive example	A18	FeTiAl	A	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Inventive example	A19	FeTiAl	C	TiO_x, Al_2O_3 *3	Dispersion over the entire pipe thickness
Inventive example	A20	FeTi, Al	D	TiO_x, Al_2O_3 *3	Dispersion in rows near the center of pipe thickness
Inventive example	A21	FeTiAl	D	TiO_x, Al_2O_3	Dispersion in rows near the center of pipe thickness
Inventive example	A22	FeTiAl	D	TiO_x, Al_2O_3	Dispersion over the entire pipe thickness
Inventive example	A23	FeTi, Al	D	TiO_x, Al_2O_3	Dispersion in rows near the center of pipe thickness
Inventive example	A24	FeTiAl	D	TiO_x, Al_2O_3 *3	Dispersion over the entire pipe thickness
Inventive example	A25	FeTi, Al	D	TiO_x, Al_2O_3 *3	Dispersion over the entire pipe thickness
Inventive example	A26	FeTiAl	D	TiO_x, Al_2O_3	Dispersion in rows near the center of pipe thickness
Inventive example	A27	FeTi, Al	D	TiO_x, Al_2O_3 *3	Dispersion over the entire rod diameter
Inventive example	A28	FeTiAl	D	TiO_x, Al_2O_3 *3	Dispersion in rows near the center of rod diameter
Inventive example	A29	FeTi, Al	D	TiO_x, Al_2O_3	Dispersion in rows near the center of rod diameter
Inventive example	A30	FeTiAl	D	TiO_x, Al_2O_3	Dispersion over the entire rod diameter
Inventive example	A31	FeTi, Al	D	TiO_x, Al_2O_3	Dispersion in rows near the center of rod diameter
Inventive example	A32	FeTiAl	D	TiO_x, Al_2O_3 *3	Dispersion over the entire rod diameter
Inventive example	A33	FeTiAl	D	TiO_x, Al_2O_3 *3	Dispersion over the entire wire diameter
Inventive example	A34	FeTiAl	D	TiO_x, Al_2O_3	Dispersion in rows near the center of wire diameter
Comparative example	B1	Al	B	Al_2O_3 *4	Dispersion over the entire sheet thickness
Comparative example	B2	Ti	C	TiO_x *5	Dispersion in rows near the center of sheet thickness
Comparative example	B3	Al, CaSi	D	CaO, Al_2O_3	Elongation in the rolling direction over the entire pipe thickness
Comparative example	B4	FeSi, FeMn	D	MnO, SiO_2	Elongation in the rolling direction near the center of rod diameter
Comparative example	B5	FeTi, Al	D	Al_2O_3 *4	Dispersion over the entire pipe thickness
Comparative example	B6	FeTiAl	D	TiO_x *5	Dispersion in rows near the center of rod diameter

Table 3

	No.	Micro-Vickers hardness *6, Hv	Maximum diameter of inclusion particle *7, μm	Number of inclusion particles *8, piece/kg	Ratio of occurrence of defects *9, %
Inventive example	A1	612	179	35.0	0.5
Inventive example	A2	1174	185	32.3	0.4
Inventive example	A3	1236	163	27.4	0.3
Inventive example	A4	1001	158	22.5	0.5
Inventive example	A5	1288	178	26.3	0.4
Inventive example	A6	870	166	24.4	0.3
Inventive example	A7	1062	257	43.2	0.5
Inventive example	A8	723	138	18.5	0.4
Inventive example	A9	692	187	9.7	0.6
Inventive example	A10	612	203	9.9	0.2
Inventive example	A11	946	154	9.5	0.2
Inventive example	A12	1220	165	8.7	0.7
Inventive example	A13	1206	189	8.8	0.2
Inventive example	A14	1001	287	19.5	0.5
Inventive example	A15	1288	264	18.3	0.6
Inventive example	A16	870	122	4.3	0.3
Inventive example	A17	1102	374	246	1.2
Inventive example	A18	1058	326	123	1.4
Inventive example	A19	974	230	26.5	0.0
Inventive example	A20	665	212	22.2	0.0
Inventive example	A21	642	206	35.4	0.0
Inventive example	A22	782	198	32.1	0.0
Inventive example	A23	743	187	30.2	0.0
Inventive example	A24	612	177	27.3	0.0
Inventive example	A25	738	199	33.3	0.0
Inventive example	A26	647	209	34.6	0.0
Inventive example	A27	615	257	33.8	1.2
Inventive example	A28	820	273	27.9	0.8
Inventive example	A29	782	267	27.3	0.5
Inventive example	A30	631	196	25.2	1.1
Inventive example	A31	664	188	22.4	0.7
Inventive example	A32	897	206	19.6	1.1
Inventive example	A33	872	234	20.1	0.9
Inventive example	A34	673	165	17.5	0.6
Comparative example	B1	1933	460	250	2.8
Comparative example	B2	1402	324	175	3.2
Comparative example	B3	359	230	43	8.3
Comparative example	B4	443	297	47	16.3
Comparative example	B5	1505	387	44	6.2
Comparative example	B6	1476	366	42	8.9

Example 2

[0036] Pieces of rolled steel were produced by a vertical bend-type continuous casting machine under the condition that the slab size was 245 mm thickness × 1200 to 1600 mm width, the casting speed was 1.4 to 1.7 m/min, and the temperature of molten steel in the tundish was 1560°C. After that, the slabs were hot-rolled, and then the pieces of hot-rolled steel were subjected to acid pickling, cold rolling, annealing and secondary cold rolling when necessary. In this way, products shown in Tables 4, 7 and 10 were produced.

[0037] Deoxidizing alloy used in the production process and the principal components contained in the crystallized phase of oxide inclusions are shown in Tables 5, 8, 11 and 12. The hardness of oxide inclusions, the existing formation

and the ratio of occurrence of defects are shown in Tables 6, 9 and 13. It can be seen from these tables that the present invention can greatly reduce the defects of products caused by oxide inclusions so that the productivity can be enhanced.

[0038] The components of the crystallized phases of inclusions shown in Tables 5, 8 and 12 were identified in such a manner that the inclusions extracted from pieces of rolled steel of full thickness, the weight of which was 1 ± 0.1 kg, by means of slime electrolytic extraction (the minimum mesh was 38 μm) were identified by SEM having EDX. Further, concerning the detected additional component, the content was found from the integral intensity of the peak of the characteristic X-rays.

[0039] The existing inclusion formations shown in Tables 5, 8 and 12 on the section of the rolling direction were determined by the profiles of products as follows.

[0040] In the case of a sheet, the full thickness of a section parallel to the rolling direction was observed by an optical microscope, and the existing inclusion formation was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50) which was taken at a position where the inclusion exists.

[0041] In the case of a wire, the full thickness of a section parallel to the drawing direction (the rolling direction) was observed by an optical microscope, and the existing inclusion formation was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50) which was taken at a position where the inclusion exists.

[0042] In the cases of a pipe and rod, local positions, which were located below the front or the rear surface by 0.1 mm, 1/8t, 1/4t, 3/8t, 1/2t, 5/8t, 3/4t and 7/8t wherein t is thickness, were observed by an optical microscope, and the existing formation of inclusion was determined by an optical microscopic photograph (the magnification was 400 and the total number of field of view was 50 for each local position) which was taken at a position where the inclusion exists.

[0043] In this connection, the meaning of *1 to *11 shown in Tables 4 to 13 are described as follows.

*1: Tr: Not more than the lower limit capable of being analyzed, -: Ca or Mg is not added.

*2: Level of dissolved oxygen

A: Not less than 400 ppm, B: Not less than 200 ppm and lower than 400 ppm, C: Not less than 100 ppm and lower than 200 ppm, D: Lower than 100 ppm

*3: Principal component in the crystallized phase is controlled by a quantity of alloy added in the process of deoxidation.

*4: Not more than 10 weight % of MnO and SiO_2 are contained as additional components in the crystallized phase.

*5: Not more than 5 weight % of TiO_x is contained as an additional component in the crystallized phase.

*6: Not more than 5 weight % of Al_2O_3 is contained as an additional component in the crystallized phase.

*7: Not more than 5 weight % of Al_2O_3 is contained as an additional component in the crystallized phase, and not more than 10 weight % of MnO and SiO_2 are also contained as additional components in the crystallized phase.

*8: An average is calculated at the room temperature for 10 particles of inclusion when a load of 25 g is given to each of three positions with respect to one type of inclusion.

*9, *10: The maximum diameter of the inclusion particles and the number of the inclusion particles are controlled by dissolved oxygen before deoxidation.

The method of measuring the maximum diameter of the inclusion particles is described below. Inclusions, which were extracted by means of slime electrolytic extraction (the minimum mesh was 38 μm) from a piece of rolled steel of full thickness of the weight of 1 ± 0.1 kg, were photographed by a stereoscopic microscope, the magnification of which was 40, and the averages of the major and the minor axis of the inclusion particles on the photograph were found with respect to all the inclusion particles, and the maximum value of the thus found averages was determined to be the maximum diameter of the inclusion particles. The number of the inclusion particles was found as follows. The number of all the inclusion particles, which was extracted by means of the slime electrolytic extraction (the minimum mesh was 38 μm) and observed by an optical microscope (the magnification was 100) was converted into the number per the unit of 1 kg.

*11: The ratio of occurrence of defects is determined by the following formulas.

In the case of a sheet, the ratio of occurrence of sliver flaws on the surface of the sheet is (total length of sliver flaws/length of a coil)

In the case of a pipe, the ratio of occurrence of UST defects in the electroseamed zone is (number of pipes in which the defects occurred/number of inspected pipes)

In the case of a rod and wire, the ratio of occurrence of surface flaws is (number of coils in which defects occur/total number of inspected coils)

Table 4

	No.	Profile of product	Basic composition of steel (mass %, however, Ca is represented by ppm, and the rest are iron and inevitable impurities.)							
			C	Si	Mn	P	S	Ti	sol. Al	Ca*1
Inventive example	A1	Sheet	0.0005	0.035	0.55	0.017	0.006	0.057	0.048	30
Inventive example	A2	Sheet	0.0024	0.005	0.76	0.027	0.011	0.002	0.002	47
Inventive example	A3	Sheet	0.0043	0.011	0.14	0.040	0.017	0.017	0.008	Tr
Inventive example	A4	Sheet	0.0067	0.019	0.33	0.007	0.022	0.032	0.018	13
Inventive example	A5	Sheet	0.0022	0.013	0.36	0.019	0.013	0.019	0.007	42
Inventive example	A6	Sheet	0.0045	0.018	0.53	0.032	0.019	0.036	0.016	Tr
Inventive example	A7	Sheet	0.0063	0.032	0.81	0.042	0.024	0.078	0.062	17
Inventive example	A8	Sheet	0.0007	0.006	0.11	0.005	0.005	0.003	0.001	31
Inventive example	A9	Sheet	0.02	0.077	0.65	0.015	0.004	0.057	0.029	5
Inventive example	A10	Sheet	0.04	0.006	0.91	0.024	0.010	0.001	0.002	12
Inventive example	A11	Sheet	0.07	0.030	0.15	0.038	0.028	0.016	0.010	27
Inventive example	A12	Sheet	0.10	0.053	0.40	0.005	0.024	0.033	0.020	3
Inventive example	A13	Sheet	0.03	0.005	0.13	0.017	0.015	0.021	0.008	11
Inventive example	A14	Sheet	0.05	0.038	0.43	0.033	0.018	0.034	0.017	29
Inventive example	A15	Sheet	0.12	0.057	0.69	0.044	0.022	0.088	0.069	43
Inventive example	A16	Sheet	0.0095	0.084	0.88	0.006	0.006	0.002	0.003	8
Inventive example	A17	Sheet	0.0067	0.013	0.16	0.033	0.014	0.014	0.033	25
Inventive example	A18	Sheet	0.029	0.038	0.39	0.042	0.007	0.048	0.003	45
Inventive example	A19	Pipe	0.022	0.36	1.18	0.008	0.0005	0.219	0.086	Tr
Inventive example	A20	Pipe	0.12	0.019	1.69	0.010	0.048	0.003	0.002	17
Inventive example	A21	Pipe	0.24	0.135	0.13	0.014	0.009	0.076	0.033	41
Inventive example	A22	Pipe	0.32	0.252	0.66	0.004	0.013	0.149	0.065	1
Inventive example	A23	Pipe	0.10	0.153	0.67	0.005	0.008	0.088	0.036	3
Inventive example	A24	Pipe	0.26	0.243	1.24	0.011	0.067	0.157	0.050	48
Inventive example	A25	Pipe	0.29	0.014	1.82	0.016	0.010	0.230	0.081	4
Inventive example	A26	Pipe	0.014	0.144	0.09	0.003	0.021	0.006	0.006	19
Inventive example	A27	Rod	0.51	0.36	1.18	0.008	0.024	0.200	0.076	21
Inventive example	A28	Rod	0.55	0.019	1.69	0.010	0.060	0.005	0.004	Tr
Inventive example	A29	Rod	0.59	0.135	0.13	0.014	0.096	0.062	0.030	22
Inventive example	A30	Rod	0.62	0.252	0.66	0.004	0.133	0.133	0.071	37
Inventive example	A31	Rod	0.56	0.153	0.67	0.005	0.050	0.076	0.033	47
Inventive example	A32	Rod	0.58	0.243	1.24	0.011	0.095	0.147	0.048	19
Inventive example	A33	Wire	0.64	0.014	1.82	0.016	0.128	0.219	0.084	33
Inventive example	A34	Wire	0.49	0.144	0.09	0.003	0.017	0.008	0.003	41
Comparative example	B1	Sheet	0.0005	0.011	0.14	0.027	0.022	0.014	0.033	-
Comparative example	B2	Sheet	0.04	0.053	0.40	0.038	0.012	0.048	0.002	-
Comparative example	B3	Sheet	0.03	0.019	0.16	0.011	0.008	0.014	0.002	-
Comparative example	B4	Sheet	0.0022	0.013	0.36	0.019	0.013	0.019	0.007	-
Comparative example	B5	Sheet	0.001	0.005	0.20	0.010	0.011	0.012	0.011	13
Comparative example	B6	Pipe	0.24	0.153	0.67	0.004	0.067	0.000	0.057	30
Comparative example	B7	Rod	0.62	0.243	1.24	0.005	0.128	0.000	0.003	-
Comparative example	B8	Pipe	0.26	0.014	0.71	0.014	0.078	0.002	0.120	5
Comparative example	B9	Rod	0.64	0.144	1.35	0.002	0.140	0.267	0.003	47

Table 5

	No.	Deoxidizing alloy	Level of dissolved oxygen before adding deoxidizing alloy *2	Principal component in crystallized phase *3	Existing inclusion formation on the section in the rolling direction
Inventive example	A1	FeTi, Al, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A2	FeTiAl, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A3	FeTi, Al, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A4	FeTiAl, FeCa	B	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A5	FeTi, Al, FeCa	B	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A6	FeTiAl, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A7	FeTiAl, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A8	FeTi, Al, CaSi	B	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A9	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A10	FeTi, Al, Ca	C	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A11	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A12	FeTi, Al, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A13	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A14	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A15	FeTiAl, FeCa	C	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A16	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A17	FeTi, Al, CaSi	A	TiO_x, Al_2O_3, CaO	Dispersion over the entire sheet thickness
Inventive example	A18	FeTiAl, CaSi	A	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of sheet thickness
Inventive example	A19	FeTiAl, CaSi	C	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire pipe thickness
Inventive example	A20	FeTi, Al, Ca	D	TiO_x, Al_2O_3, CaO *4	Dispersion in rows near the center of pipe thickness
Inventive example	A21	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of pipe thickness
Inventive example	A22	FeTiAl, Ca	D	TiO_x, Al_2O_3, CaO	Dispersion over the entire pipe thickness
Inventive example	A23	FeTi, Al, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion over the entire pipe thickness
Inventive example	A24	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire pipe thickness
Inventive example	A25	FeTi, Al, CaSi	D	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire pipe thickness
Inventive example	A26	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of pipe thickness
Inventive example	A27	FeTi, Al, FeCa	D	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire rod diameter
Inventive example	A28	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO *4	Dispersion in rows near the center of rod diameter
Inventive example	A29	FeTi, Al, Ca	D	TiO_x, Al_2O_3, CaO	Dispersion over the entire rod diameter
Inventive example	A30	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion over the entire rod diameter
Inventive example	A31	FeTi, Al, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion over the entire rod diameter
Inventive example	A32	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire rod diameter
Inventive example	A33	FeTiAl, FeCa	D	TiO_x, Al_2O_3, CaO *4	Dispersion over the entire wire diameter
Inventive example	A34	FeTiAl, CaSi	D	TiO_x, Al_2O_3, CaO	Dispersion in rows near the center of wire diameter
Comparative example	B1	Al	B	Al_2O_3 *5	Dispersion over the entire sheet thickness
Comparative example	B2	Ti	C	TiO_x *6	Dispersion in rows near the center of sheet thickness
Comparative example	B3	FeTi, Al	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B4	FeTiAl	A	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B5	Ti, CaSi	B	TiO_x, CaO	Elongation in the rolling direction near the center of sheet thickness
Comparative example	B6	Al, FeCa	D	Al_2O_3, CaO	Elongation in the rolling direction over the entire pipe thickness
Comparative example	B7	FeSi, FeMn	D	MnO, SiO_2	Elongation in the rolling direction near the center of rod diameter
Comparative example	B8	FeTi, Al, CaSi	D	Al_2O_3, CaO *5	Elongation in the rolling direction over the entire pipe thickness
Comparative example	B9	FeTiAl, Ca	D	TiO_x, CaO *6	Elongation in the rolling direction near the center of rod diameter

Table 6

	No.	Micro-Vickers hardness *8, Hv	Maximum diameter of inclusion particle *9, µm	Number of inclusion particles *10, piece/kg	Ratio of occurrence of defects *11, %
Inventive example	A1	581	163	35.4	0.4
Inventive example	A2	1115	168	32.5	0.3
Inventive example	A3	1174	150	27.7	0.2
Inventive example	A4	950	146	22.7	0.4
Inventive example	A5	1223	162	26.6	0.3
Inventive example	A6	826	153	24.6	0.2
Inventive example	A7	1009	226	43.6	0.4
Inventive example	A8	687	130	18.7	0.3
Inventive example	A9	658	170	9.8	0.4
Inventive example	A10	643	182	10.0	0.1
Inventive example	A11	899	143	9.6	0.1
Inventive example	A12	1159	152	8.8	0.4
Inventive example	A13	1146	171	8.9	0.1
Inventive example	A14	950	250	19.7	0.4
Inventive example	A15	1223	231	18.5	0.4
Inventive example	A16	826	118	4.3	0.2
Inventive example	A17	1047	345	98.5	1.0
Inventive example	A18	1005	332	79.0	1.2
Inventive example	A19	925	204	26.8	0
Inventive example	A20	632	190	22.4	0
Inventive example	A21	610	185	35.8	0
Inventive example	A22	743	178	32.4	0
Inventive example	A23	706	170	30.5	0
Inventive example	A24	643	162	27.6	0
Inventive example	A25	701	179	33.6	0
Inventive example	A26	615	187	34.9	0
Inventive example	A27	645	226	34.1	1.0
Inventive example	A28	779	238	28.2	0.6
Inventive example	A29	743	234	27.6	0.3
Inventive example	A30	600	177	25.5	0.9
Inventive example	A31	634	170	22.6	0.5
Inventive example	A32	852	185	19.8	0.9
Inventive example	A33	829	207	20.3	0.7
Inventive example	A34	640	152	17.7	0.4
Comparative example	B1	2010	465	262.5	2.9
Comparative example	B2	1452	314	183.8	3.4
Comparative example	B3	773	252	45.1	0.6
Comparative example	B4	1054	318	146.0	1.3
Comparative example	B5	491	275	44.1	4.6
Comparative example	B6	377	322	35.2	8.7
Comparative example	B7	465	234	19.4	17.1
Comparative example	B8	382	237	46.2	6.5
Comparative example	B9	520	248	33.6	9.3

Table 7

	No.	Profile of product	Basic composition of steel (mass %, however, Mg is represented by ppm, and the rest are iron and inevitable impurities.)							
			C	Si	Mn	P	S	Ti	sol. Al	Mg*1
Inventive example	A35	Sheet	0.0006	0.037	0.58	0.012	0.005	0.058	0.052	29
Inventive example	A36	Sheet	0.0027	0.006	0.77	0.023	0.012	0.002	0.001	45
Inventive example	A37	Sheet	0.0048	0.012	0.12	0.038	0.019	0.018	0.005	2
Inventive example	A38	Sheet	0.0068	0.021	0.33	0.005	0.025	0.035	0.021	16
Inventive example	A39	Sheet	0.0023	0.015	0.35	0.022	0.011	0.021	0.006	43
Inventive example	A40	Sheet	0.0049	0.020	0.52	0.031	0.021	0.038	0.013	Tr
Inventive example	A41	Sheet	0.0069	0.033	0.88	0.042	0.025	0.078	0.065	19
Inventive example	A42	Sheet	0.0003	0.007	0.10	0.005	0.003	0.003	0.003	32
Inventive example	A43	Sheet	0.03	0.078	0.62	0.014	0.004	0.059	0.031	4
Inventive example	A44	Sheet	0.05	0.004	0.92	0.022	0.012	0.001	0.002	15
Inventive example	A45	Sheet	0.08	0.040	0.15	0.032	0.031	0.018	0.015	28
Inventive example	A46	Sheet	0.11	0.054	0.48	0.006	0.026	0.035	0.023	Tr
Inventive example	A47	Sheet	0.04	0.003	0.11	0.018	0.017	0.020	0.007	10
Inventive example	A48	Sheet	0.05	0.042	0.42	0.035	0.016	0.037	0.017	32
Inventive example	A49	Sheet	0.13	0.059	0.66	0.045	0.025	0.082	0.072	44
Inventive example	A50	Sheet	0.008	0.086	0.85	0.004	0.005	0.002	0.002	9
Inventive example	A51	Sheet	0.006	0.016	0.15	0.030	0.013	0.016	0.030	22
Inventive example	A52	Sheet	0.030	0.041	0.32	0.048	0.005	0.049	0.003	46
Inventive example	A53	Pipe	0.020	0.42	1.21	0.005	0.0006	0.222	0.087	2
Inventive example	A54	Pipe	0.11	0.022	1.67	0.009	0.052	0.002	0.002	18
Inventive example	A55	Pipe	0.28	0.141	0.11	0.012	0.008	0.079	0.036	43
Inventive example	A56	Pipe	0.35	0.268	0.68	0.003	0.011	0.150	0.065	Tr
Inventive example	A57	Pipe	0.11	0.158	0.69	0.008	0.007	0.082	0.038	5
Inventive example	A58	Pipe	0.26	0.255	1.26	0.015	0.071	0.162	0.052	49
Inventive example	A59	Pipe	0.31	0.015	1.91	0.019	0.001	0.245	0.082	3
Inventive example	A60	Pipe	0.016	0.146	0.08	0.003	0.025	0.004	0.004	20
Inventive example	A61	Rod	0.53	0.380	1.21	0.009	0.029	0.210	0.080	22
Inventive example	A62	Rod	0.56	0.021	1.72	0.012	0.062	0.003	0.003	3
Inventive example	A63	Rod	0.60	0.141	0.11	0.016	0.102	0.072	0.032	25
Inventive example	A64	Rod	0.65	0.255	0.68	0.003	0.143	0.145	0.071	32
Inventive example	A65	Rod	0.58	0.152	0.62	0.005	0.049	0.068	0.031	46
Inventive example	A65	Rod	0.59	0.256	1.22	0.013	0.099	0.141	0.049	15
Inventive example	A67	Wire	0.67	0.016	1.80	0.018	0.133	0.231	0.082	30
Inventive example	A68	Wire	0.51	0.143	0.07	0.004	0.022	0.006	0.002	44
Comparative example	B10	Sheet	0.0006	0.013	0.13	0.028	0.023	0.012	0.035	-
Comparative example	B11	Sheet	0.05	0.055	0.37	0.031	0.011	0.052	0.001	-
Comparative example	B12	Sheet	0.02	0.023	0.12	0.009	0.007	0.011	0.003	-
Comparative example	B13	Sheet	0.003	0.015	0.35	0.021	0.015	0.017	0.009	-
Comparative example	B14	Sheet	0.0009	0.004	0.18	0.012	0.016	0.010	0.013	10
Comparative example	B15	Pipe	0.26	0.163	0.69	0.003	0.072	0.000	0.063	32
Comparative example	B16	Rod	0.63	0.258	1.28	0.004	0.132	0.000	0.002	-
Comparative example	B17	Pipe	0.27	0.015	0.69	0.018	0.081	0.001	0.115	3
Comparative example	B18	Rod	0.66	0.155	1.48	0.003	0.142	0.285	0.030	46

Table 8

	No.	Deoxidizing alloy	Level of dissolved oxygen before adding deoxidizing alloy *2	Principal component in crystallized phase *3	Existing inclusion formation on the section in the rolling direction
Inventive example	A35	FeTi, Al, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A36	FeTiAl, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A37	FeTi, Al, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A38	FeTiAl, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A39	FeTi, Al, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A40	FeTiAl, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A41	FeTiAl, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A42	FeTi, Al, FeMgSi	B	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A43	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A44	FeTi, Al, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A45	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A46	FeTi, Al, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A47	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A48	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A49	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A50	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A51	FeTi, Al, FeMgSi	A	TiO_x, Al_2O_3, MgO	Dispersion over the entire sheet thickness
Inventive example	A52	FeTiAl, FeMgSi	A	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A53	FeTiAl, FeMgSi	C	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A54	FeTi, Al, Mg	D	TiO_x, Al_2O_3, MgO *4	Dispersion in rows near the center of pipe thickness
Inventive example	A55	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire pipe thickness
Inventive example	A56	FeTiAl, Mg-Coke	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire pipe thickness
Inventive example	A57	FeTi, Al, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire pipe thickness
Inventive example	A58	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A59	FeTi, Al, FeMgSi	D	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A60	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of pipe thickness
Inventive example	A61	FeTi, Al, FeMgSi	D	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire rod diameter
Inventive example	A62	FeTiAl, Mg-Coke	D	TiO_x, Al_2O_3, MgO *4	Dispersion in rows near the center of rod diameter
Inventive example	A63	FeTi, Al, Mg	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire rod diameter
Inventive example	A64	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire rod diameter
Inventive example	A65	FeTi, Al, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion over the entire rod diameter
Inventive example	A66	FeTiAl, Mg-Coke	D	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire rod diameter
Inventive example	A67	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO *4	Dispersion over the entire wire diameter
Inventive example	A68	FeTiAl, FeMgSi	D	TiO_x, Al_2O_3, MgO	Dispersion in rows near the center of wire diameter
Comparative example	B10	Al	B	Al_2O_3 *5	Dispersion over the entire sheet thickness
Comparative example	B11	Ti	C	TiO_x *6	Dispersion in rows near the center of sheet thickness
Comparative example	B12	FeTi, Al	C	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B13	FeTiAl	A	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B14	Ti, FeMgSi	B	TiO_x, MgO	Dispersion in rows near the center of sheet thickness
Comparative example	B15	Al, FeMgSi	D	Al_2O_3, MgO	Dispersion over the entire sheet thickness
Comparative example	B16	FeSi, FeMn	D	MnO, SiO_2	Elongation in the rolling direction near the center of rod diameter
Comparative example	B17	FeTi, Al, FeMgSi	D	Al_2O_3, MgO *5	Dispersion over the entire sheet thickness
Comparative example	B18	FeTiAl, Mg	D	TiO_x, MgO *6	Dispersion in rows near the center of rod diameter

Table 9

	No.	Micro-Vickers hardness *8, Hv	Maximum diameter of inclusion particle *9, µm	Number of inclusion particles *10, piece/kg	Ratio of occurrence of defects *11, %
Inventive example	A35	612	160	34.5	0.4
Inventive example	A36	1245	167	37.1	0.3
Inventive example	A37	1206	145	30.2	0.2
Inventive example	A38	982	137	26.3	0.4
Inventive example	A39	1275	153	29.5	0.3
Inventive example	A40	854	145	27.6	0.3
Inventive example	A41	1085	218	44.8	0.4
Inventive example	A42	715	130	21.2	0.2
Inventive example	A43	683	170	10.5	0.4
Inventive example	A44	672	175	12.5	0.2
Inventive example	A45	925	145	11.9	0.3
Inventive example	A46	1283	142	10.2	0.4
Inventive example	A47	1271	165	10.8	0.4
Inventive example	A48	972	328	21.2	0.3
Inventive example	A49	1254	319	20.5	0.4
Inventive example	A50	849	106	6.2	0.3
Inventive example	A51	1072	305	102.0	1.1
Inventive example	A52	1070	292	82.0	0.9
Inventive example	A53	945	195	29.5	0
Inventive example	A54	655	183	25.6	0
Inventive example	A55	644	172	36.8	0
Inventive example	A56	773	176	37.6	0
Inventive example	A57	783	163	34.4	0
Inventive example	A58	644	152	33.2	0
Inventive example	A59	728	170	26.1	0
Inventive example	A60	645	173	34.8	0
Inventive example	A61	676	218	36.5	0.9
Inventive example	A62	748	232	25.5	0.5
Inventive example	A63	755	244	30.2	0.6
Inventive example	A64	645	168	28.7	0.8
Inventive example	A65	643	167	30.2	0.9
Inventive example	A66	885	170	21.2	0.8
Inventive example	A67	854	194	22.0	0.7
Inventive example	A68	640	149	20.3	0.4
Comparative example	B10	2010	496	256.8	3.1
Comparative example	B11	1453	358	196.2	3.5
Comparative example	B12	795	241	43.2	0.5
Comparative example	B13	1052	326	154.3	1.3
Comparative example	B14	1826	268	41.3	5.2
Comparative example	B15	2384	303	32.6	8.9
Comparative example	B16	475	220	20.5	16.7
Comparative example	B17	2243	225	43.5	7.2
Comparative example	B18	1785	235	35.2	9.1

Table 10

	No.	Profile of product	Basic composition of steel (mass %, however, Ca and Mg are represented by ppm, and the rest are iron and inevitable impurities.)								
			C	Si	Mn	P	S	Ti	sol. Al	Ca*1	Mg*1
Inventive example	A69	Sheet	0.0004	0.039	0.56	0.010	0.004	0.052	0.048	28	2
Inventive example	A70	Sheet	0.0029	0.008	0.79	0.025	0.014	0.001	0.002	49	16
Inventive example	A71	Sheet	0.0050	0.010	0.14	0.036	0.022	0.017	0.006	2	43
Inventive example	A72	Sheet	0.0066	0.023	0.35	0.003	0.027	0.036	0.025	11	Tr
Inventive example	A73	Sheet	0.0021	0.017	0.38	0.018	0.009	0.025	0.005	43	19
Inventive example	A74	Sheet	0.0052	0.018	0.50	0.035	0.026	0.032	0.016	Tr	32
Inventive example	A75	Sheet	0.0062	0.035	0.90	0.042	0.028	0.078	0.066	19	4
Inventive example	A76	Sheet	0.0003	0.009	0.12	0.004	0.002	0.002	0.004	29	15
Inventive example	A77	Sheet	0.02	0.076	0.63	0.015	0.005	0.062	0.033	3	28
Inventive example	A78	Sheet	0.04	0.004	0.99	0.026	0.015	0.002	0.001	10	Tr
Inventive example	A79	Sheet	0.08	0.045	0.21	0.030	0.035	0.019	0.017	25	10
Inventive example	A80	Sheet	0.13	0.052	0.43	0.007	0.026	0.031	0.025	3	32
Inventive example	A81	Sheet	0.05	0.002	0.10	0.019	0.018	0.022	0.008	10	44
Inventive example	A82	Sheet	0.06	0.044	0.38	0.036	0.016	0.038	0.019	25	9
Inventive example	A83	Sheet	0.14	0.057	0.67	0.044	0.022	0.089	0.078	41	22
Inventive example	A84	Sheet	0.009	0.088	0.85	0.005	0.003	0.002	0.003	6	46
Inventive example	A85	Sheet	0.005	0.012	0.11	0.033	0.011	0.017	0.035	23	2
Inventive example	A86	Sheet	0.028	0.044	0.35	0.052	0.004	0.052	0.004	42	18
Inventive example	A87	Pipe	0.022	0.40	1.18	0.006	0.0007	0.232	0.088	1	43
Inventive example	A88	Pipe	0.14	0.020	1.72	0.010	0.055	0.002	0.001	12	Tr
Inventive example	A89	Pipe	0.32	0.145	0.09	0.015	0.009	0.077	0.039	44	5
Inventive example	A90	Pipe	0.42	0.262	0.62	0.005	0.011	0.125	0.067	Tr	19
Inventive example	A91	Pipe	0.10	0.165	0.71	0.009	0.008	0.088	0.038	2	3
Inventive example	A92	Pipe	0.28	0.243	1.32	0.016	0.074	0.168	0.051	47	20
Inventive example	A93	Pipe	0.33	0.013	1.90	0.021	0.001	0.240	0.085	3	22
Inventive example	A94	Pipe	0.018	0.139	0.06	0.003	0.022	0.003	0.002	17	3
Inventive example	A95	Rod	0.57	0.392	1.23	0.008	0.028	0.230	0.075	23	25
Inventive example	A96	Rod	0.56	0.023	1.75	0.011	0.063	0.004	0.003	2	32
Inventive example	A97	Rod	0.62	0.147	0.11	0.018	0.123	0.077	0.035	26	46
Inventive example	A98	Rod	0.68	0.258	0.66	0.004	0.147	0.156	0.075	39	9
Inventive example	A99	Rod	0.52	0.148	0.58	0.006	0.042	0.066	0.033	48	30
Inventive example	A100	Rod	0.62	0.263	1.32	0.015	0.100	0.144	0.052	11	44
Inventive example	A101	Wire	0.67	0.012	1.92	0.021	0.138	0.238	0.081	32	10
Inventive example	A102	Wire	0.50	0.155	0.05	0.004	0.028	0.005	0.003	42	35
Comparative example	B19	Sheet	0.0004	0.012	0.12	0.022	0.019	0.011	0.028	-	-
Comparative example	B20	Sheet	0.04	0.058	0.38	0.034	0.010	0.055	0.001	-	-
Comparative example	B21	Sheet	0.01	0.022	0.11	0.007	0.005	0.013	0.004	-	-
Comparative example	B22	Sheet	0.003	0.013	0.38	0.022	0.012	0.021	0.012	-	-
Comparative example	B23	Sheet	0.0008	0.003	0.15	0.014	0.018	0.009	0.000	13	32
Comparative example	B24	Pipe	0.23	0.172	0.72	0.002	0.078	0.000	0.069	30	46
Comparative example	B25	Rod	0.66	0.268	1.31	0.005	0.142	0.000	0.003	-	-
Comparative example	B26	Pipe	0.28	0.012	0.72	0.023	0.078	0.001	0.120	5	45
Comparative example	B27	Rod	0.61	0.165	1.52	0.004	0.138	0.268	0.020	47	29

Table 11

	No.	Deoxidizing alloy	Level of dissolved oxygen before adding deoxidizing alloy *2
Inventive example	A69	FeTi, Al, FeCa, FeMgSi	B
Inventive example	A70	FeTiAl, Ca, Mg	B
Inventive example	A71	FeTi, Al, Ca, Mg	B
Inventive example	A72	FeTiAl, CaSi, Mg	B
Inventive example	A73	FeTi, Al, Ca, FeMgSi	B
Inventive example	A74	FeTiAl, Ca, FeMgSi	B
Inventive example	A75	FeTiAl, CaSi, FeMgSi	B
Inventive example	A76	FeTi, Al, FeCa, Mg	B
Inventive example	A77	FeTiAl, CaSi, FeMgSi	C
Inventive example	A78	FeTi, Al, FeCa, Mg	C
Inventive example	A79	FeTiAl, CaSi, FeMgSi	C
Inventive example	A80	FeTi, Al, CaSi, FeMgSi	C
Inventive example	A81	FeTiAl, Ca, Mg	C
Inventive example	A82	FeTiAl, FeCa, FeMgSi	C
Inventive example	A83	FeTiAl, CaSi, FeMgSi	C
Inventive example	A84	FeTiAl, CaSi, FeMgSi	C
Inventive example	A85	FeTi, Al, FeCa, FeMgSi	A
Inventive example	A86	FeTiAl, FeCa, FeMgSi	A
Inventive example	A87	FeTiAl, CaSi, FeMgSi	C
Inventive example	A88	FeTi, Al, FeCa, Mg	D
Inventive example	A89	FeTiAl, CaSi, FeMgSi	D
Inventive example	A90	FeTiAl, CaSi, Mg-Coke	D
Inventive example	A91	FeTi, Al, CaSi, FeMgSi	D
Inventive example	A92	FeTiAl, CaSi, FeMgSi	D
Inventive example	A93	FeTi, Al, FeCa, FeMgSi	D
Inventive example	A94	FeTiAl, FeCa, FeMgSi	D
Inventive example	A95	FeTi, Al, CaSi, FeMgSi	D
Inventive example	A96	FeTiAl, Ca, Mg-Coke	D
Inventive example	A97	FeTi, Al, CaSi, Mg	D
Inventive example	A98	FeTiAl, CaSi, FeMgSi	D
Inventive example	A99	FeTi, Al, CaSi, FeMgSi	D
Inventive example	A100	FeTiAl, CaSi, Mg-Coke	D
Inventive example	A101	FeTiAl, FeCa, Mg	D
Inventive example	A102	FeTiAl, CaSi, FeMgSi	D
Comparative example	B19	Al	B
Comparative example	B20	Ti	C
Comparative example	B21	FeTi, Al	C
Comparative example	B22	FeTiAl	A
Comparative example	B23	Ti, FeCa, Mg	B
Comparative example	B24	Al, CaSi, FeMgSi	D
Comparative example	B25	FeSi, FeMn	D
Comparative example	B26	FeTi, Al, FeMgSi	D
Comparative example	B27	FeTiAl, Mg-Coke	D

Table 12

	No.	Principal component in crystallized phase *3	Existing inclusion formation on the section in the rolling direction
Inventive example	A69	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A70	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A71	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A72	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A73	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A74	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A75	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A76	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A77	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A78	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A79	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A80	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A81	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A82	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A83	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A84	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A85	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire sheet thickness
Inventive example	A86	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of sheet thickness
Inventive example	A87	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A88	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion in rows near the center of pipe thickness
Inventive example	A89	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire pipe thickness
Inventive example	A90	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire pipe thickness
Inventive example	A91	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire pipe thickness
Inventive example	A92	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A93	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire pipe thickness
Inventive example	A94	TiO_x, Al_2O_3, CaO, MgO	Dispersion in rows near the center of pipe thickness
Inventive example	A95	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire rod diameter
Inventive example	A96	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion in rows near the center of rod diameter
Inventive example	A97	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire rod diameter
Inventive example	A98	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire rod diameter
Inventive example	A99	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire rod diameter
Inventive example	A100	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire rod diameter
Inventive example	A101	TiO_x, Al_2O_3, CaO, MgO *4	Dispersion over the entire wire diameter
Inventive example	A102	TiO_x, Al_2O_3, CaO, MgO	Dispersion over the entire wire diameter
Comparative example	B19	Al_2O_3 *5	Dispersion over the entire sheet thickness
Comparative example	B20	TiO_x *6	Dispersion in rows near the center of sheet thickness
Comparative example	B21	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B22	TiO_x, Al_2O_3	Dispersion in rows near the center of sheet thickness
Comparative example	B23	TiO_x, CaO, MgO	Dispersion in rows near the center of sheet thickness
Comparative example	B24	Al_2O_3, CaO, MgO	Dispersion over the entire pipe thickness
Comparative example	B25	MnO, SiO_2	Elongation in the rolling direction near the center of rod diameter
Comparative example	B26	Al_2O_3, CaO, MgO *5	Dispersion over the entire pipe thickness
Comparative example	B27	TiO_x, CaO, MgO *7	Dispersion in rows near the center of rod diameter

Table 13

	No.	Micro-Vickers hard-ness *8, Hv	Maximum diameter of inclusion particle *9, μm	Number of inclusion particles *10, piece/kg	Ratio of occur-rence of defects *11, %
Inventive example	A69	609	133	31.1	0.2
Inventive example	A70	1235	140	30.5	0.1
Inventive example	A71	1203	122	24.3	0.0
Inventive example	A72	995	115	22.2	0.2
Inventive example	A73	1284	103	26.3	0.1
Inventive example	A74	941	95	24.4	0.1
Inventive example	A75	1056	248	34.6	0.2
Inventive example	A76	753	120	15.8	0.0
Inventive example	A77	698	135	5.3	0.2
Inventive example	A78	635	144	7.8	0.0
Inventive example	A79	1002	126	8.8	0.1
Inventive example	A80	1262	142	7.8	0.3
Inventive example	A81	1291	122	9.5	0.2
Inventive example	A82	945	184	8.1	0.1
Inventive example	A83	1254	192	18.3	0.3
Inventive example	A84	835	95	3.8	0.1
Inventive example	A85	1108	308	104.0	0.8
Inventive example	A86	1005	313	82.5	0.7
Inventive example	A87	963	155	23.7	0
Inventive example	A88	645	160	19.8	0
Inventive example	A89	675	142	30.6	0
Inventive example	A90	758	195	33.6	0
Inventive example	A91	687	152	28.5	0
Inventive example	A92	624	128	30.4	0
Inventive example	A93	758	138	20.2	0
Inventive example	A94	654	136	29.8	0
Inventive example	A95	758	198	30.9	0.5
Inventive example	A96	654	262	19.6	0.3
Inventive example	A97	753	224	26.8	0.4
Inventive example	A98	621	139	24.5	0.5
Inventive example	A99	683	157	26.3	0.5
Inventive example	A100	958	195	17.2	0.4
Inventive example	A101	868	183	17.9	0.5
Inventive example	A102	632	130	15.5	0.2
Comparative example	B19	2005	486	238.5	3.0
Comparative example	B20	1380	368	200.3	3.3
Comparative example	B21	756	196	36.8	0.5
Comparative example	B22	998	352	163.5	1.2
Comparative example	B23	1527	234	36.5	3.8
Comparative example	B24	2068	275	27.5	8.0
Comparative example	B25	462	210	18.5	16.8
Comparative example	B26	1952	192	38.4	7.1
Comparative example	B27	1468	208	30.7	7.3

[0044] As can be seen from the above explanations, the present invention provides rolled steel having few inclusion defects in which fine particles of oxide inclusions are dispersed.

[0045] Therefore, it is possible for the present invention to contribute to the development of industry by providing rolled steel having few inclusion defects in which the conventional problems are completely solved.

Claims

1. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and the crystallized phases of oxide inclusions exist in steel.

2. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and the crystallized phases of oxide inclusions exist in steel being dispersed in rows in the rolling direction near the center of rolled steel.

3. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, Micro-Vickers hardness at the room temperature of the oxide inclusions is 600 to 1300 Hv, and the crystallized phases of oxide inclusions exist in steel.

4. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, Micro-Vickers hardness at the room temperature of the oxide inclusions is 600 to 1300 Hv, and the crystallized phases of oxide inclusions exist in steel being dispersed in rows in the rolling direction near the center of rolled steel.

5. Rolled steel having few defects of inclusion, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and further composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, and the crystallized phases of oxide inclusions exist in steel.

6. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and further composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, and the crystallized phases of oxide inclusions exist in steel being dispersed in rows in the rolling direction near the center of steel.

7. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and further composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, Micro-Vickers hardness of the oxide inclusions at the room temperature is 600 to 1300 Hv, and the crystallized phases of oxide inclusions exist in steel.

8. Rolled steel having few inclusion defects, the basic composition of which is C: 0.0002 to 0.7 mass %, Si: 0.001 to 0.5 mass %, Mn: 0.005 to 2.0 mass %, P: 0.001 to 0.05 mass %, S: 0.0005 to 0.15 mass %, Ti: 0.001 to 0.25 mass % and dissolved Al: 0.001 to 0.1 mass %, the selective composition of which is Ca: not more than 50 ppm and Mg: not more than 50 ppm, at least one of Ca and Mg being contained, wherein created oxide inclusions are mainly composed of a crystallized phase, the principal component of which is titanium oxide, and a crystallized phase, the principal component of which is alumina, and further composed of at least one of a crystallized phase, the principal component of which is CaO, and a crystallized phase, the principal component of which is MgO, Micro-Vickers hardness of the oxide inclusions at the room temperature is 600 to 1300 Hv, and the crystallized phases of oxide inclusions exist in steel being dispersed in rows in the rolling direction near the center of steel.

9. Rolled steel according to any one of claims 1 to 8, wherein the maximum diameter of particles of oxide inclusions obtained by slime extraction is not more than 300 μm.

10. Rolled steel having few inclusion defects according to claim 9 wherein the number of particles of oxide inclusions obtained by slime extraction, the diameters of which are not less than 38 μm, is not more than 50 pieces/kg.